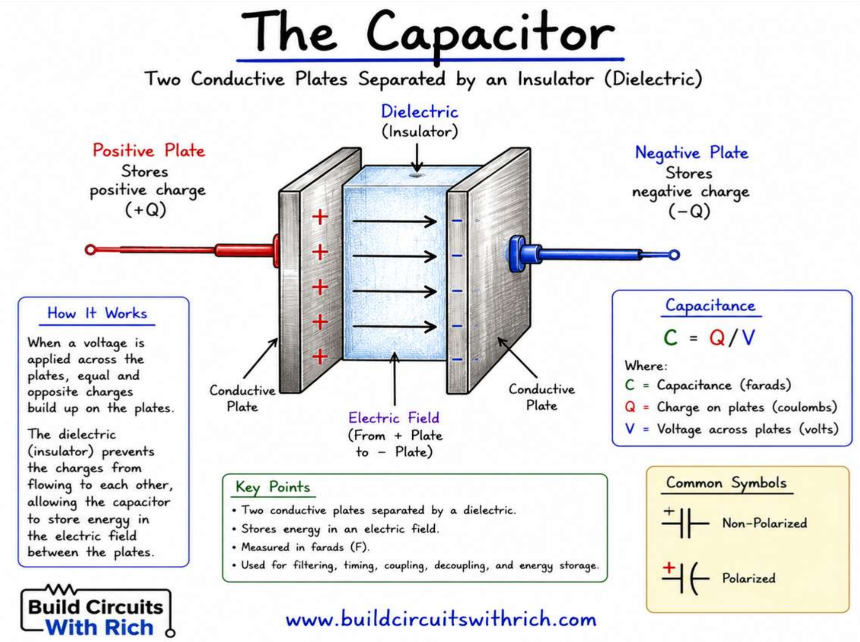
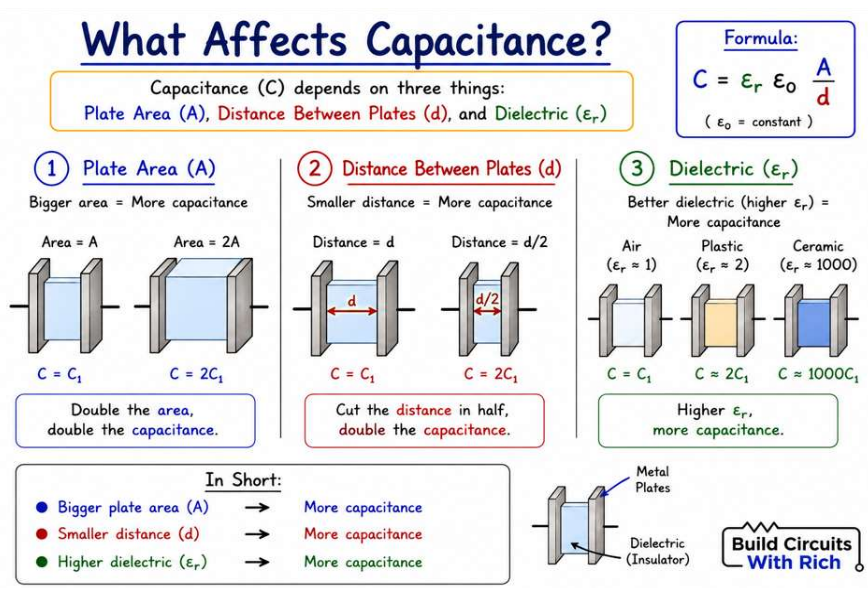
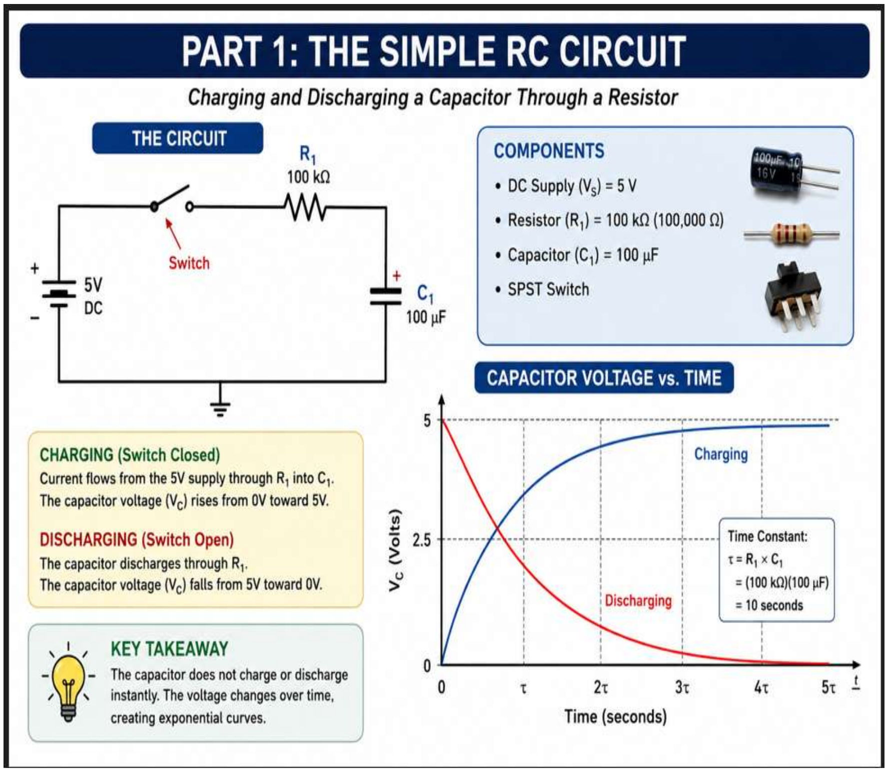
The Amazing Capacitor – Part 2 | How Capacitors Charge and Discharge

Quick Review From Last Video:

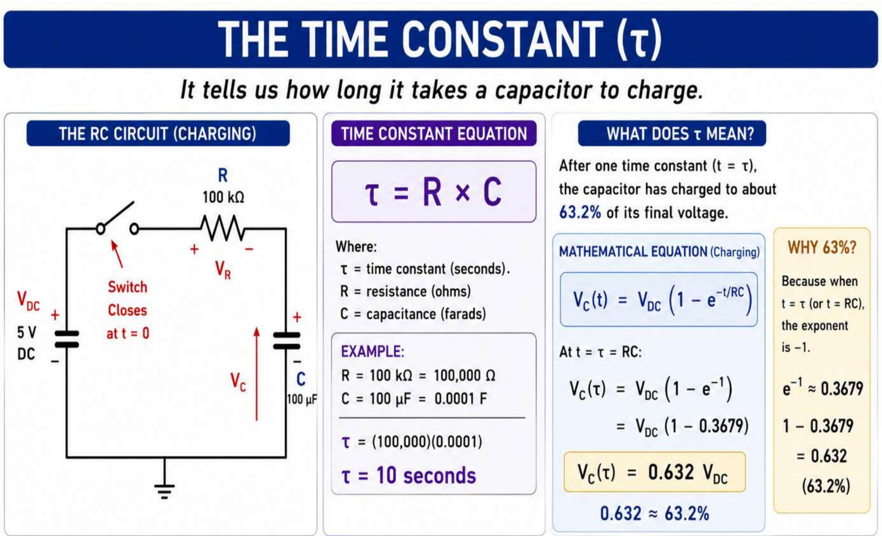






RC Circuit Charging:

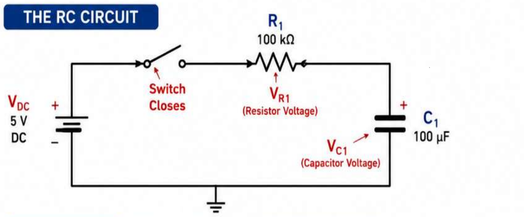
We can predict exactly how long it takes for the capacitor to charge:



RC CIRCUIT CHARGING – VOLTAGES & CURRENT OVER TIME

As the capacitor charges, the resistor voltage and current decrease.

THE RC CIRCUIT



KIRCHHOFF'S VOLTAGE LAW (KVL)

At all times during charging:

$$V_{DC} = V_{R1} + V_{C1}$$

OHM'S LAW (CURRENT THROUGH RESISTOR)

$$I = \frac{V_{R1}}{R_1}$$ where R_1 = 100 kΩ

TIME (During Charging)	V_{DC} (Supply Voltage)	V_{R1} (Resistor Voltage)	V_{C1} (Capacitor Voltage)	KVL CHECK $V_{DC} = V_{R1} + V_{C1}$	I_{R1} or I (Current Through R_1) $I = V_{R1}$ / 100 kΩ
1. Start (t = 0)	5 V	5 V	0 V	5 = 5 + 0	5 / 100kΩ = 50 µA
2. Early	5 V	4 V	1 V	5 = 4 + 1	4 / 100kΩ = 40 µA
3. Mid	5 V	3 V	2 V	5 = 3 + 2	3 / 100kΩ = 30 µA
4. Mid	5 V	2 V	3 V	5 = 2 + 3	2 / 100kΩ = 20 µA
5. Late	5 V	1 V	4 V	5 = 1 + 4	1 / 100kΩ = 10 µA
6. Fully Charged (Steady State)	5 V	0 V	5 V	5 = 0 + 5	0 / 100kΩ = 0 µA (≈ 0 µA)

KEY TAKEAWAYS

- As the capacitor charges, V_{C1} increases.
- As V_{C1} increases, V_{R1} decreases.
- Since $I = V_{R1} / R_1$, the current through the resistor decreases.
- KVL is always true: $V_{DC} = V_{R1} + V_{C1}$ at every instant.

In this example:
R_1 = 100 kΩ
C_1 = 100 µF

$R \times C = 100\,k\Omega \times 100\,uf = 10\,s = \tau$

$V_c = V_{DC}(1 - e^{-\frac{t}{RC}})$

$\tau = 10$

$t = 10\,s$

$\tau = 10\,s \quad V_c = V_{DC}(1 - e^{-\frac{10}{10}})$

$V_c = V_D(1 - e^{-1})$

$t = 1\,s \quad V_c = V_{DC}(1 - e^{-\frac{1}{10}})$

$t = 10\,s = \tau$

$t = 1\,s \rightarrow V_c = 5(1 - e^{-\frac{1}{10}}) = 0.476\,V$

$\tau = 10\,s \quad V_c = 5(1 - e^{-\frac{10}{10}}) = 3.16\,V$

side Note:

$$I_t = \frac{V_{DC} - V_{C1}}{R_1} = \frac{V_{DC} - V_{DC}(1 - e^{-\frac{t}{RC}})}{R_1} = 0 + V_{DC} \cdot e^{-\frac{t}{RC}}$$

$V_{DC} - V_{DC} + V_{DC}\,e^{-\frac{t}{RC}} = 0 + V_{DC} \cdot e^{-\frac{t}{RC}}$

$V_{R_1} = V_{DC} - V_{DC} + (V_{DC} \cdot e^{-\frac{t}{RC}})$

$V_{R_1} = 0 + (V_{DC})e^{-\frac{t}{RC}}$

$I_1 = \frac{V_{R_1}}{R_1}$

$I_t = \frac{V_{DC}}{R_1} e^{-\frac{t}{RC}}$

1.839×10^{-5}

18.39×10^{-6}

$\tau = 10 \quad \frac{5V}{100\,k\Omega} \cdot e^{-\frac{10}{10}} = 18.4\,uA$

$t = \tau = 10\,s, \quad I_t = 18.4\,uA$